REMARKS/ARGUMENTS

In the Office action dated March 10, 2004, the Examiner rejected claims 1-22, all of the claims in the application. Claims 1,2, 6-8, 16-18 and 22 were rejected under 35 U.S. C. §102(b) as being anticipated by U.S. Patent No. 5,585,148 to Suzuki *et al.* Claims 3-5, 9-15 and 19-21 were rejected under 35 U.S.C. § 103(a) as being unpatentable over '148.

In the Specification, no changes.

In the Claims, no changes.

The Invention

The invention is a method of forming a high quality silicon nitride layer at low temperature in an integrated circuit. The method of the invention employs the use of nitrogen radicals to convert silicon to a silicon nitride. The method of the invention may also form a thin nitride layer on an already-grown silicon oxide layer by displacing the oxygen at the top surface and converting at least a portion of silicon oxide to silicon nitride. The method of the invention does not use a plasma discharge, which may cause substantial damage to the silicon wafer. The method of the invention generates large quantities of nitrogen radicals on or near the surface of a silicon layer, or silicon oxide layer, which is to be converted to silicon nitride. The radicals are generated by the photolysis, or photo-dissociation, of NH_3. The light source used is a Xe_2 excimer lamp which emits at a wavelength of 172 nm, or 7.21eV in energy. The direct illumination of the wafer surface at such an energy level may generate photoelectrons and a charged surface that may participate in the nitridation process. The work function of silicon is less than 5eV, so electrons can have over 2.2eV of kinetic energy. Electron attachment of the low energy electrons may generate negatively charged species, such as NH_2^-, that are quite stable. Adsorbed molecules on

the surface of the substrate may also play a role in the nitride layer growth. The growth of the film may be assisted by a field across the growing dielectric layer where a positively charged interface attracts negative ions.

The Applied Art

U.S. Patent No. 5,585,148 to Suzuki *et al.* describes a process for depositing a variety of layers of material on a silicon wafer. Among the material deposited is SiN, however, such deposition does not use photo-dissociation of a nitrogen-containing gas, as described in the Application: a layer of SiN, as described in the applied portion of the reference, is CVD'd by a chemical reaction of NH_3 and SiH_4, which are passed over a wafer, and which results in deposition of a SiN layer. Although the reference describes the use of a light source, such light source is not of sufficient energy to photo-dissociate NH_3 into N or N_2, as would easily be recognized by one of ordinary skill in the art. The source of energy for the CVD of various material in the '148 reference is a plasma which is generated in a plasma chamber portion of the apparatus described in the reference, and which is applicable to all embodiments of the invention described and claimed in '148.

The Claims

Claim 1 recites: "...dissociating the nitrogen-containing gas into nitrogen with a excimer lamp and flowing the nitrogen over the silicon wafer;..." The Examiner has applied '148, col. 9, lines 47-50, which is a portion of the third example of the reference. There is no mention of "dissociation," nor of an excimer lamp in this portion of the reference. Elsewhere in '148, the Patentee describes the third example as having using a plasma source, and using a light for *irradiating the surface of the wafer*. Col. 4, lines 6-24. This is a very different process than that

describes and claimed by Applicant. Claim 1 is not anticipated by any portion of '148 because '148 does not teach nor suggest that a nitrogen-containing gas is dissociated by an excimer lamp; '148 teaches that a chemical reaction between a nitrogen-containing gas an a silicon containing gas is used to form SiN, which is deposited by CVD on a silicon wafer. The use of a plasma is required by the teaching of '148; Applicant's method of invention does not require, need, or contemplate use of plasma. To eliminate the plasma from the method of the '148 patent would render the method of '148 inoperable.

Applicant claims a temperature range of between about room temperature and 400°C. The Examiner applies '148, col. 9, lines 37-39, which recites heating the substrate to a temperature of between room temperature and several hundred degrees, however, as the elements of the claim may not be separated for examination, the Examiner must find a reference wherein photo-dissociation *and* low temperature SiN formation are present, and the Examiner has failed to provide such a reference. Applicant has provided prior art materials regarding photo-dissociation, which teach use of high temperatures, and Applicant has described a technique for photo-dissociation at a low temperature. The Examiner has not provided a reference which teaches or suggest photo-dissociation of a nitrogen-containing gas and formation of a SiN layer on a silicon wafer at low temperature. Claim 1 is allowable over the applied art.

Claims 2-6 are allowable with their allowable parent claim.

Claim 7 recites that "...said forming includes providing a positively charged interface across the nitride layer." The Examiner has applied '148, col. 9, lines 52-57 in rejecting this claim under 35 U.S. C. § 102(b). The applied portion of '148 reads:

As a result, NH_3 gas was allowed to flow through the through-holes 16 and SiH_4 gas flowed

> *through the ejection holes uniformly toward the substrate 2. The film formation was conducted to obtain a desired film thickness. Consequently a SiN film was formed uniformly with high quality on the substrate 2.*

Neither Applicant nor the undersigned can find any teaching or suggestion that the applied portion of the reference regarding "providing a positively charged interface across the nitride layer." Claim 7 is allowable over the applied art.

Claim 8 recites that the silicon wafer used for deposition of the SiN layer has a layer of silicon oxide on the upper surface thereof. The Examiner has applied '148, col. 9, lines 58-63 in rejecting this claim under 35 U.S. C. § 102(b). The applied portion of '148 reads:

> *By changing the kind of the gas to be fed to the reaction chamber 1 and the purge chamber 14, films of insulating materials such as SiN, SiO_2, Ta_2O_5, Al_2O_3, AlN, etc.; semiconductor materials such as amorphous Si, polycrystalline Si, GaAs, etc.; metals such as Al, W, etc. can be formed.*

Again, neither Applicant nor the undersigned finds any teaching in this portion of the reference which would lead one of ordinary skill in the art to form a silicon oxide layer on a silicon wafer before placing the wafer in a chamber for formation of a layer of SiN thereon. The reference clearly teaches that other layers of material may be formed using the method of the invention, however, there is no teaching nor suggestion that multiple layers be formed. Claim 8 is allowable over the prior art of record.

Claim 9 is allowable for the reasons set forth in connection with claim 1: there is no teaching nor suggestion in '148 that an excimer lamp be used to dissociate a nitrogen-containing gas into nitrogen which is used to form a layer of SiN on a silicon wafer at a temperature of between about room temperature and 400°C. The '148 patent is applied as a 35 U.S. C. § 102 reference, and requires a plasma in order to function; Applicant's invention does not require a

plasma. Claim 9 is allowable over the prior art of record.

Claims 10-13 are allowable with their allowable parent claim.

Claim 14 is allowable for the reasons set forth in connection with claim 7.

Claim 15 is allowable for the reasons set forth in connection with claim 8.

Claim 16 is allowable for the reasons set forth in connection with claims 1 and 7.

Claims 17-21 are allowable with their allowable parent claim.

Claim 22 is allowable for the reasons set forth in connection with claim 8.

In light of the foregoing amendment and remarks, the Examiner is respectfully requested to reconsider the rejections and objections stated in the Office action, and pass the application to allowance. If the Examiner has any questions regarding the amendment or remarks, the Examiner is invited to contact the undersigned.

Provisional Request for Extension of time in Which to Respond

Should this response be deemed to be untimely, Applicants hereby request an extension of time under 37 C.F.R. § 1.136. The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any over-payment to Account No. 19-1457.

Respectfully submitted,

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David C. Ripma
Registration No. 27,672

David C. Ripma
Patent Counsel
Sharp Laboratories of America, Inc.
5750 N.W. Pacific Rim Highway
Camas, WA 98607

Telephone: (360) 834-8754
Facsimile: (360) 817-8505